Intel Unnati Industrial Training Programme – 2024

Project report - Team Innovate5

Problem statement title: PS-13 Vehicle Movement Analysis and Insight Generation in a College Campus using Edge AI

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Introduction:

Problem Description:

Managing vehicle traffic and parking on a college campus poses significant challenges. Implementing an intelligent system capable of analyzing vehicle movement, monitoring parking lot occupancy, and cross-referencing vehicles with an approved database can greatly enhance campus security and management. Our objective is to develop an Edge AI-based solution that processes real-time image data from cameras capturing vehicle photos and license plates. This solution should deliver insights on the following aspects:

Vehicle Movement Patterns: The system should analyze the frequency and timing of vehicle movement in and out of the campus, identifying peak times and movement patterns.

Parking Occupancy: The system should monitor real-time occupancy of parking lots, identifying which lots are frequently occupied and at what times.

Vehicle Matching: The system should match captured vehicle images and license plates against an approved vehicle database, identifying unauthorized vehicles.

Objectives:

- **Analyze Vehicle Movement Patterns**: Develop a system to track and analyze the frequency and timing of vehicle movements in and out of the campus. Identify peak traffic times and movement patterns.

- **Monitor Parking Lot Occupancy**: Create a real-time monitoring system for parking lot occupancy, determining which parking lots are frequently occupied and at what times.

- **Match Vehicles to Approved Database**: Implement a solution to cross-reference captured vehicle images and license plates with an approved database, identifying unauthorized vehicles on campus.

- **Real-Time Image Processing**: Ensure the system processes image data from cameras in real-time, enabling immediate analysis and response.

- **Enhance Campus Security and Management**: Utilize the insights gained from vehicle movement analysis, parking occupancy monitoring, and vehicle matching to improve overall campus security and management.

Dataset description:

Link to datasets used:

https://drive.google.com/drive/folders/1waok6rggmMI3FGxSZot-c2uHstE0K6i_?usp=sharing

Sources for all datasets have been listed in the "Data collection" subsection below.

For the various submodules of this project, a total of 3 datasets have been used for training, validation and for testing/demonstration.

1. License Plate Detection and Recognition dataset:

- A collection of 1697 images of various vehicles, annotated in the xml format.
- Labels: filepath, xmin, xmax, ymin, ymax, plate_number

2. Parking area dataset

- 1728 images of parking lots, each containing multiple parking spaces in both occupied and empty state
- Labels: 0 – empty, 1 - occupied
- Image size: 48x48

3. Vehicle movement dataset:

- 1000 rows of randomly generated vehicle movement data used for testing insight generation, stored in the CSV format.
- Fields: Date, Vehicle Name, License Plate number, In time, Out Time.

Methodology:

Methods:

To effectively address the problem statement and develop the project, the following methodology was employed:

- Implementation of System Infrastructure
- Acquisition and Storage of Data
- Development and Optimization of Models

- Real-Time Processing and Monitoring of Images
- Analysis of Data and Generation of Predictive Insights
- Integration for Security and Management Enhancement
- Testing, Deployment, and Continuous Maintenance

A. **Implementation of System Infrastructure**

Camera Installation: Deploy high-resolution cameras at all campus entry and exit points, and at strategic locations within parking lots to capture vehicle movements and parking occupancy.

Edge AI Devices: Install edge AI devices to process image data at the camera level, reducing latency and bandwidth usage.

B. **Acquisition and Storage of Data**

Image and Metadata Storage: Set up a robust database to store captured images, timestamps, vehicle identifiers, and parking occupancy data.

Approved Vehicle Database: Compile a database of approved vehicles, including license plate numbers and vehicle images for cross-referencing.

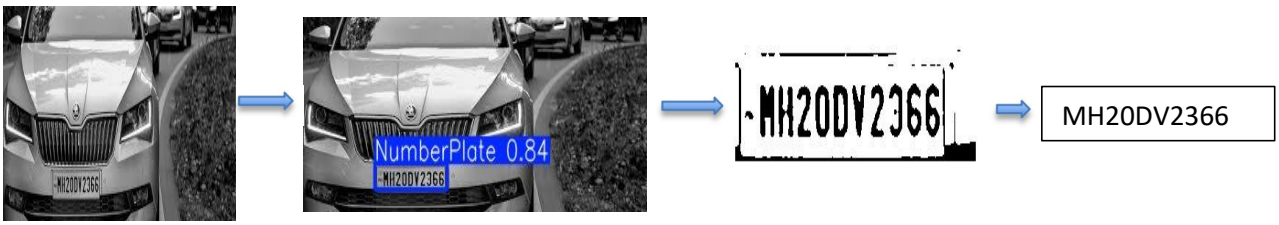
C. **Development and Optimization of Models**

Vehicle Movement Analysis: Develop and optimize algorithms to analyze the frequency and timing of vehicle movements using image processing techniques and machine learning models to identify peak traffic times and movement patterns.

Parking Occupancy Detection: Use object detection models (e.g., YOLOv8) to identify and count parked vehicles in real-time. Store this data with timestamps for historical analysis.

License Plate Recognition: Implement OCR models (e.g., easyocr) to extract license plate numbers from captured images.

Image Matching: Develop matching algorithms to compare captured vehicle images and license plates with the approved vehicle database, identifying unauthorized vehicles.



D. **Real-Time Processing and Monitoring of Images**

Edge AI Processing: Ensure edge AI devices are capable of processing image data in real-time, enabling immediate analysis and response.

Streaming Integration: Integrate video streaming capabilities to continuously process and analyze image data from cameras.

Real-Time Dashboards: Develop a comprehensive dashboard using Streamlit or similar tools to display real-time data on vehicle movements, parking occupancy, and unauthorized vehicle alerts.

E. **Analysis of Data and Generation of Predictive Insights**

Movement and Occupancy Patterns: Use machine learning models to analyze collected data, identifying movement patterns, peak traffic times, and frequently occupied parking lots.

Predictive Analytics: Implement predictive analytics to forecast vehicle movement trends and parking occupancy, aiding in proactive management.

F. **Integration for Security and Management Enhancement**

Unified System Integration: Combine insights from vehicle movement analysis, parking occupancy monitoring, and vehicle matching into a unified system for comprehensive security and management.

Alert System: Implement an alert system to notify campus authorities of unauthorized vehicles detected on campus.

Policy Development: Collaborate with campus administration to develop policies and procedures based on data insights to enhance campus security and management.

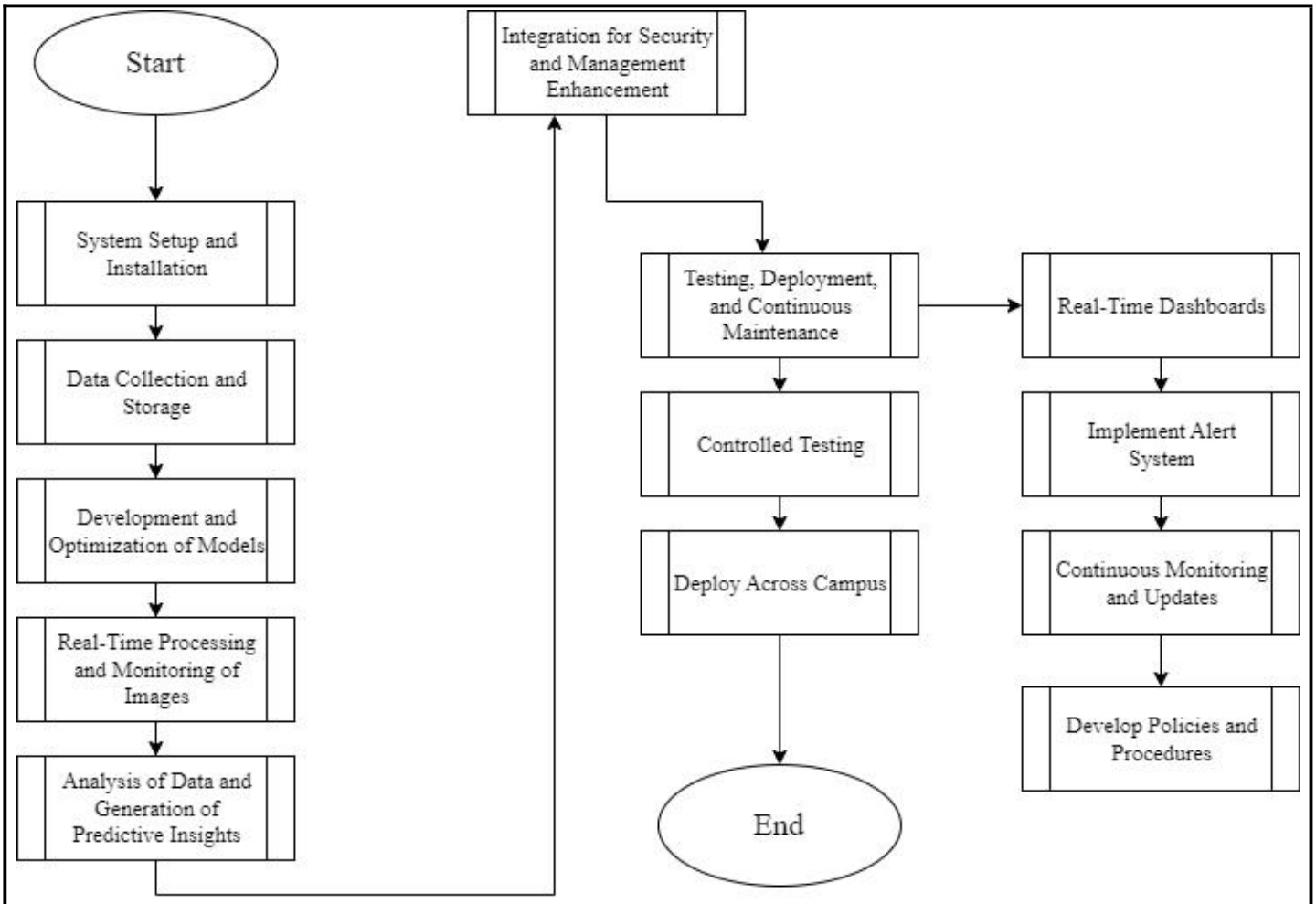
G. **Testing, Deployment, and Continuous Maintenance**

Controlled Testing: Test the system in a controlled environment to validate accuracy and performance.

Campus-Wide Deployment: Deploy the system across the campus, ensuring all components are integrated and functioning correctly.

Continuous Monitoring and Updates: Continuously monitor the system's performance and update models and algorithms as needed to maintain accuracy and efficiency.

This detailed methodology ensures a comprehensive and systematic approach to developing an intelligent vehicle management system that enhances campus security and management.



Flowchart of the Intelligent Vehicle Management System

Tools:

Programming Languages: Python, JavaScript

Web Development: HTML, CSS, JavaScript

Edge Computing Device: Raspberry Pi

Hardware: Cameras, Wires

Data Processing and Machine Learning: OpenCV, TensorFlow Lite

Backend Development: Streamlit,Python

Visualization and Dashboard: Streamlit

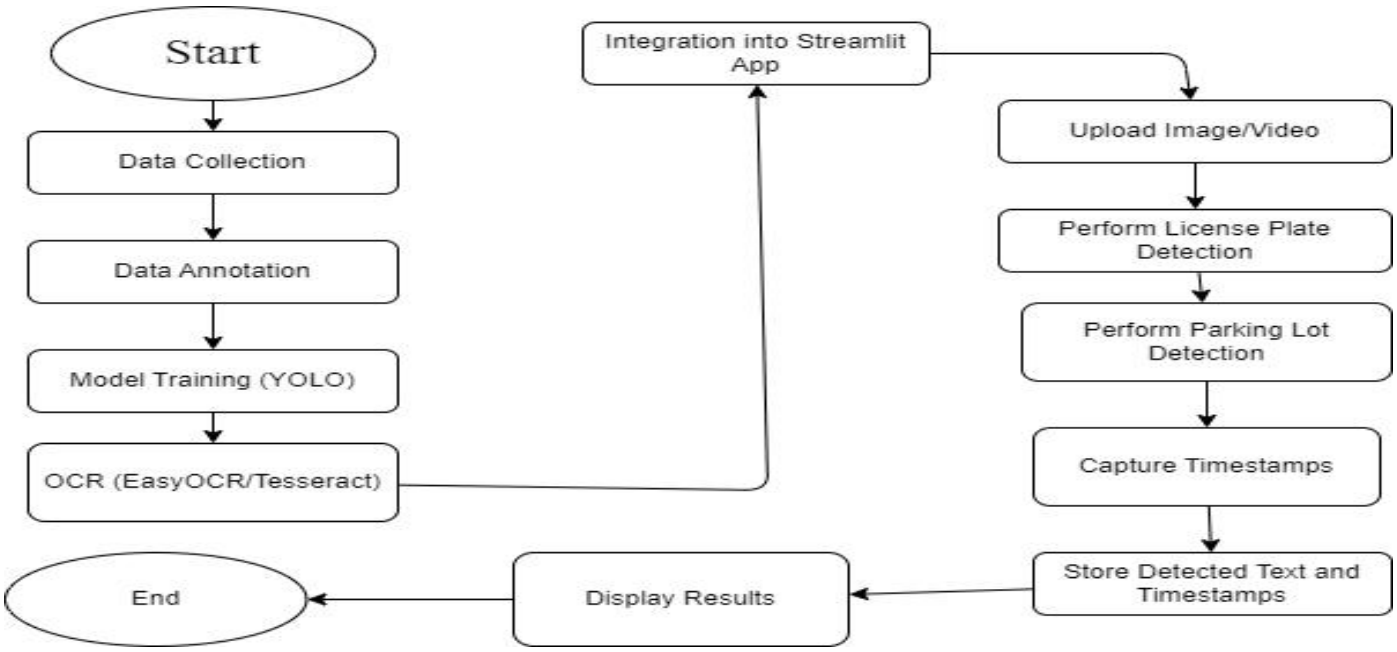
Database: MySQL

Communication and Integration: Socket.io, APIs

Development and Version Control: Visual Studio Code, Git

Deployment and Containerization: Docker

Security: Encryption Libraries, Firewall Configuration

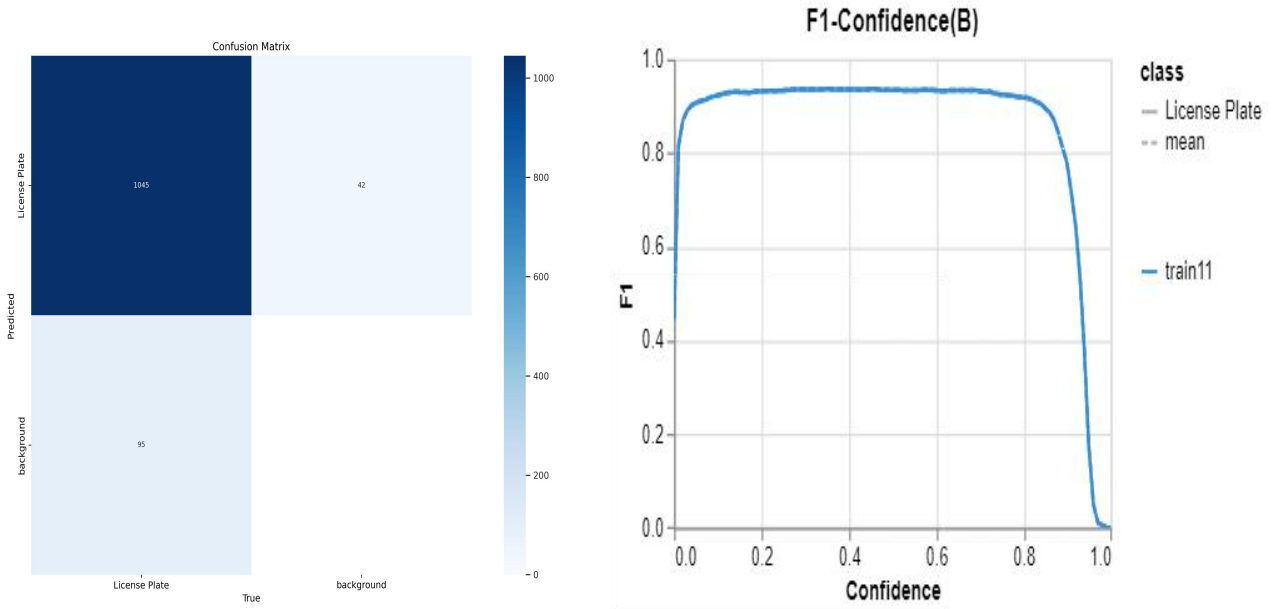


Basic template for the results integrated with web

Results:

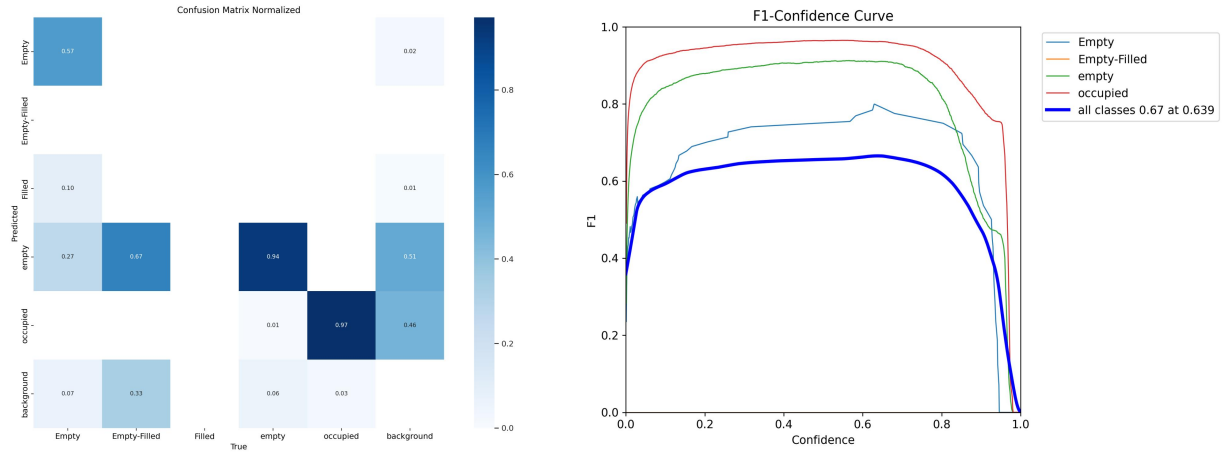
1. Model training results:

License plate detection and recognition model:



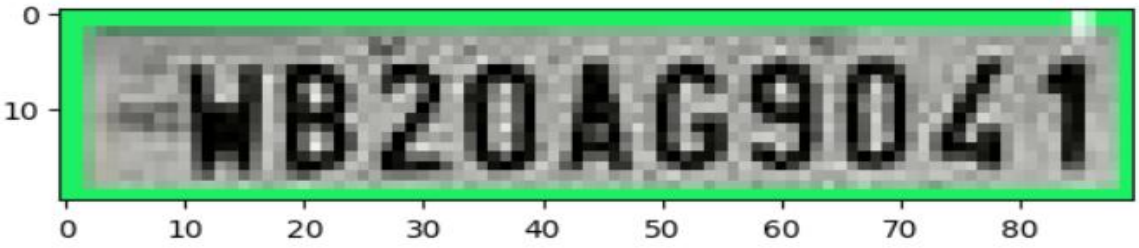
Confusion matrix and F1-Confidence Curve of license plate detection and recognition model

2. Parking Area detection model:



Confusion matrix and F1-Confidence Curve for parking space detection model

License plate detection and ocr Results:



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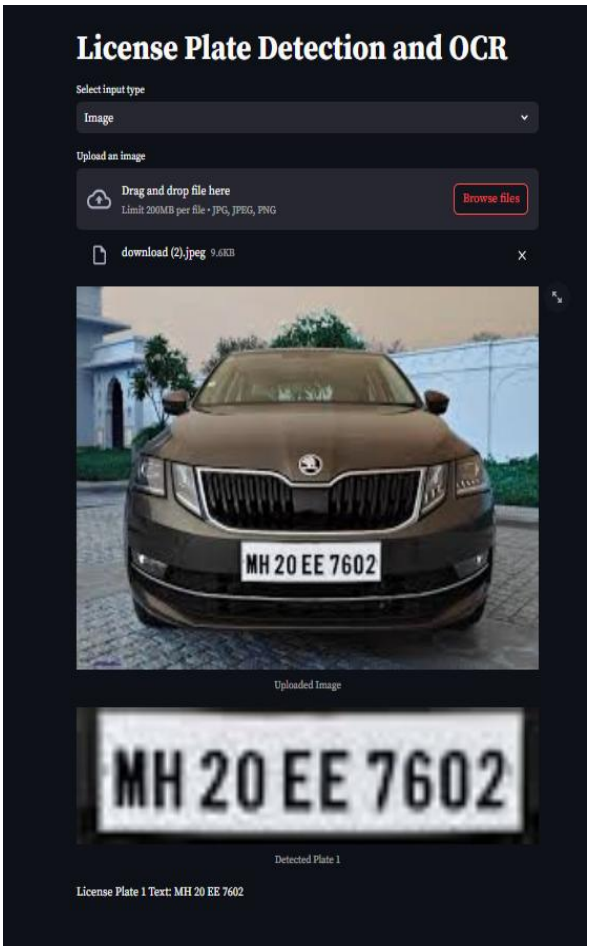
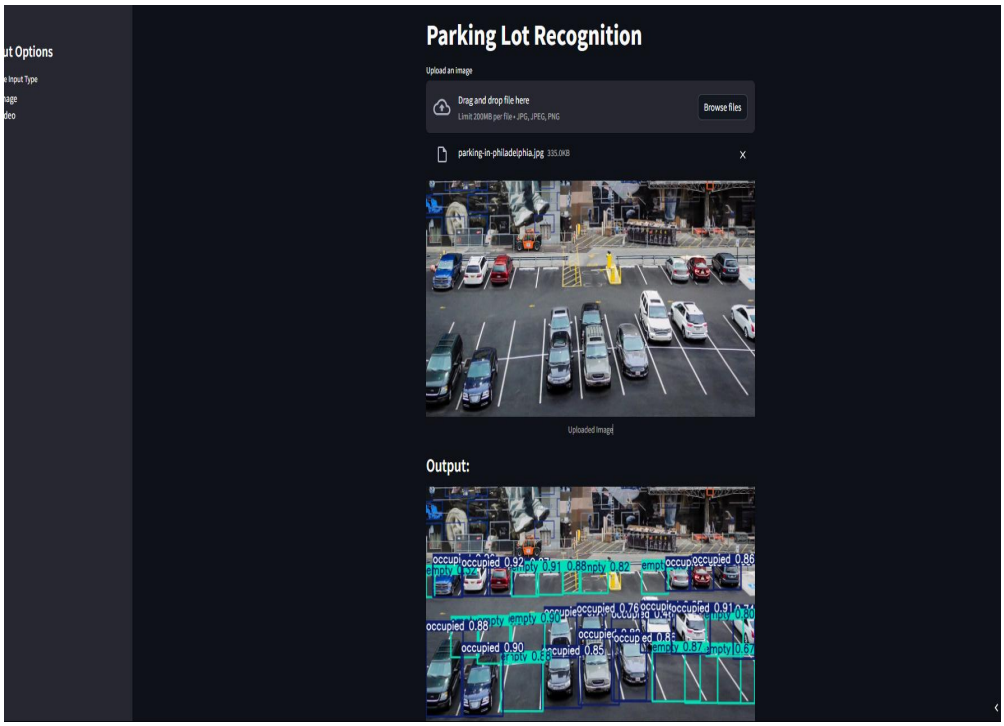


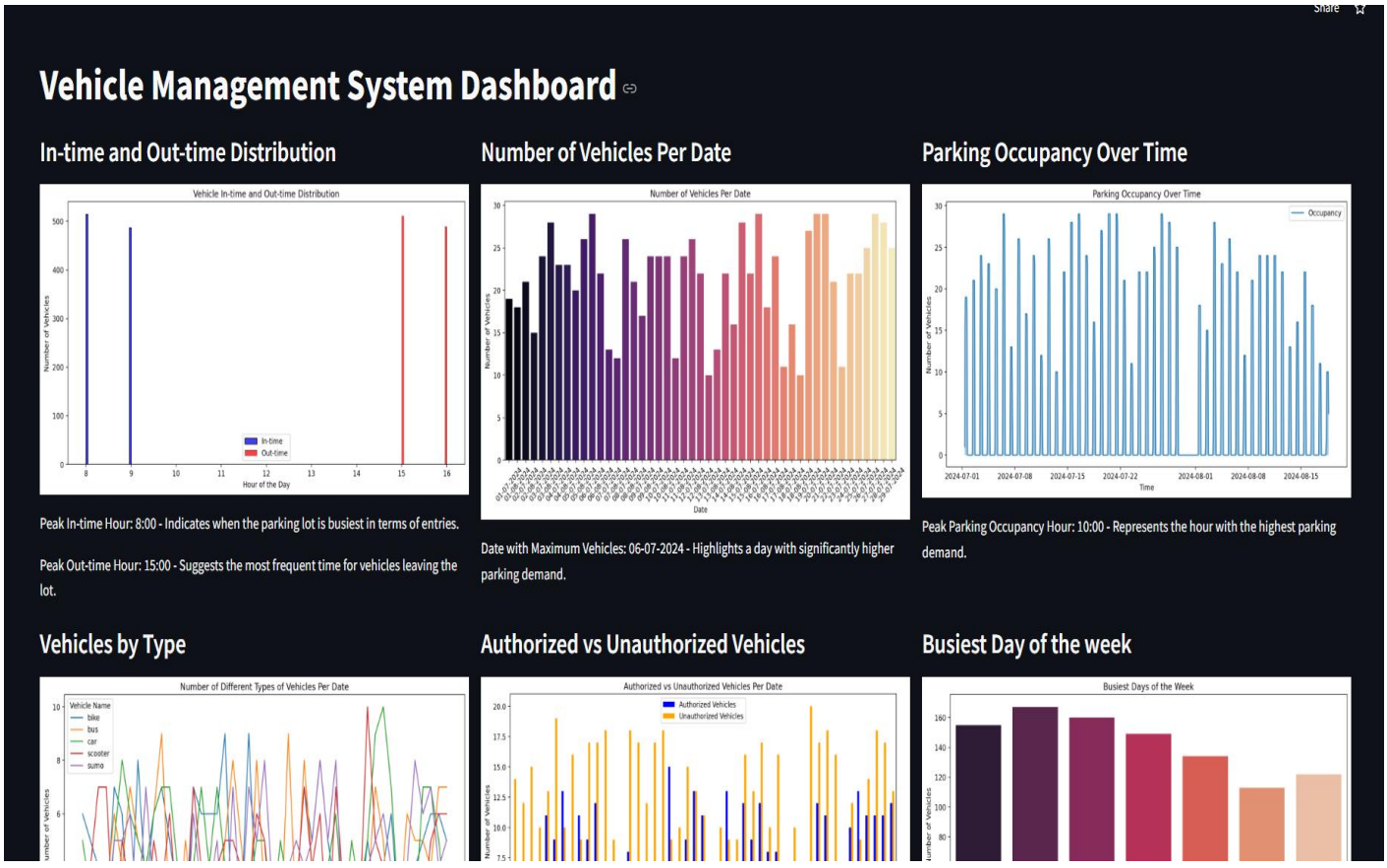
License plate detection and ocr results

Parking area model results:



Parking lot prediction results

Insights generation results:



Vehicle management system dashboard result

Findings:

- **Efficiency of Edge Computing**: Utilizing Raspberry Pi for edge computing enabled real-time image data processing with low latency, reducing the need for centralized processing.

- **High Accuracy of YOLOv8 and Pytesseract** : YOLOv8 and Pytesseract provided high accuracy in detecting and recognizing license plates, making them effective for real-time vehicle monitoring.

- **Utility of Dynamic Dashboard**: Tableau integration allowed for real-time insights into vehicle movement and parking occupancy, improving decision-making for campus management.

- **Real-Time Data Processing**: The system efficiently handled real-time data processing and analytics, ensuring timely and accurate vehicle and parking lot monitoring.

- **Scalability Potential**: The system's modular architecture allows for easy scalability and integration of additional features and technologies, making it adaptable for future enhancements.

Conclusion:

In this project, we successfully developed an intelligent vehicle management system for a college campus using edge AI and computer vision technologies. The system utilizes YOLOv8 for real-time license plate detection and pytesseract for license plate recognition, allowing us to monitor vehicle movement patterns, parking occupancy, and identify authorized vehicles. We implemented a dynamic dashboard using Tableau to provide real-time insights and improve campus security and management. Our solution demonstrates the effectiveness of edge computing in handling real-time data processing and analytics at the source.

Future scope:

- **Enhanced Vehicle Recognition**: Improve vehicle recognition accuracy by incorporating advanced machine learning models to distinguish between different vehicle types and colors.

- **Scalability**: Extend the system to manage larger or multiple campuses, integrating data from various sources and handling a higher volume of vehicles.

- **Integration with IoT Devices**: Integrate with IoT devices like smart parking sensors, automated barriers, and traffic lights to create a comprehensive smart campus ecosystem.

- **Predictive Analytics**: Implement predictive analytics to forecast parking occupancy and vehicle movement patterns for better resource management and planning.

- **Mobile Application**: Develop a mobile app for real-time parking availability, vehicle entry/exit notifications, and navigation assistance for students and staff.

References:

https://towardsai.net/p/machine-learning/anpr-with-yolov8

https://blog.streamlit.io/crafting-a-dashboard-app-in-python-using-streamlit/

https://blog.roboflow.com/build-a-parking-lot-monitoring-system/

https://medium.com/the-research-nest/parking-space-detection-using-deep-learning-9fc99a63875e

Github link:https://github.com/doli-hemanth-sai/INTEL_UTP_PS_13